

Rare Decays in B Factories

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Topics:

(Semi)Leptonic Decays

Analysis strategy

$B^+ \rightarrow K^+ \nu \bar{\nu}$, $\tau^+ \nu_\tau$, $B^0 \rightarrow \nu \bar{\nu}(\gamma)$, $\tau^+ \tau^-$ (BaBar and Belle)

$B_s^0 \rightarrow \mu^+ \mu^- (\phi)$ (Tevatron)

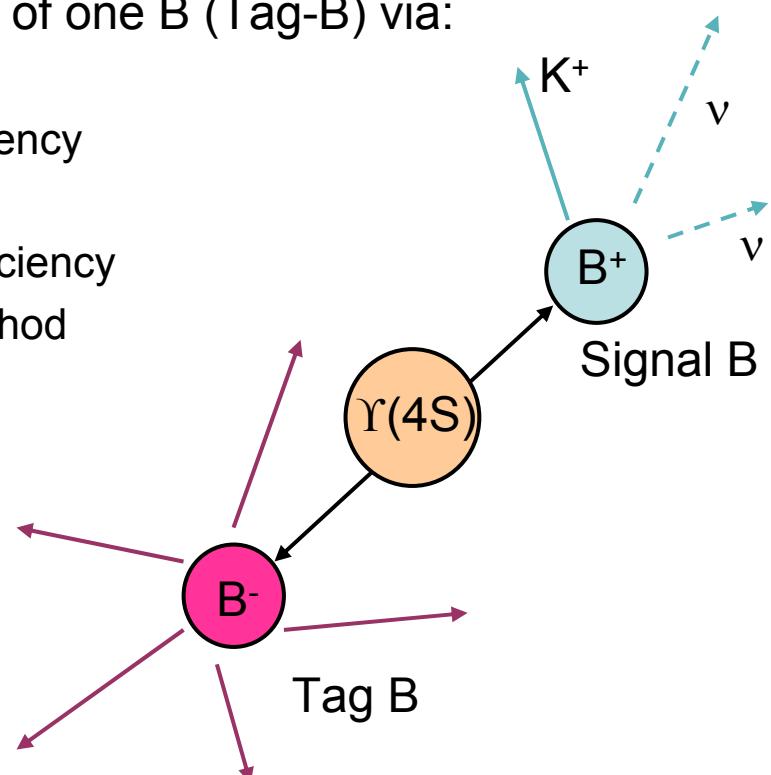
Lepton Flavour Violation τ decays

$\tau \rightarrow \ell \gamma$, $\ell h h'$

Conclusion

(Semi)leptonic decays: Analysis strategy

- Rare decays of $B \rightarrow \tau\tau, \tau\nu, K\nu\nu$ have two or more neutrinos in an event
 - Experimentally challenging
 - Require more kinematic constraints
 - Event selection criteria are exploited in each decay study
- General technique: exclusive reconstruction of one B (Tag- B) via:
 - Hadronic Tag B decays: $B \rightarrow D^0(*) X$
Full kinematic information, but lower efficiency
 - Semileptonic Tag B decays: $B \rightarrow D^0(*) \ell \nu$
Less kinematic constraints, but higher efficiency
 - Tag efficiency checked with “double tag” method
- Remaining tracks and clusters are used for recoil B (signal B)
- E_{extra} (BaBar) ; E_{ECL} (Belle) : Remaining photon energy in the calorimeter after reconstructing the two- B .



(Semi)leptonic decays: Analysis strategy (cont'd)



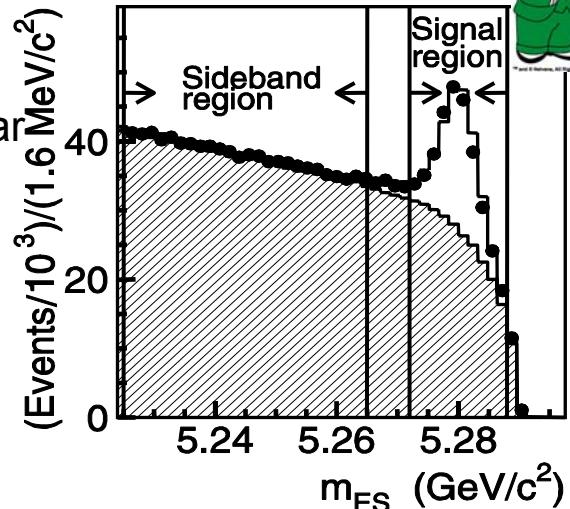
- Hadronic Tag analysis:**

energy -substituted mass (m_{ES}) ,energy difference (ΔE) - BaBar
beam energy constrained mass (M_{bc}), ΔE - Belle

$$m_{ES} \equiv \sqrt{E_{beam}^{*2} - p_B^{*2}} \sim m_B$$

$$\Delta E \equiv E_B^* - E_{beam}^* \sim 0$$

E_{beam} : Beam energy
 E_B , p_B :B meson energy and momentum
(in CM)

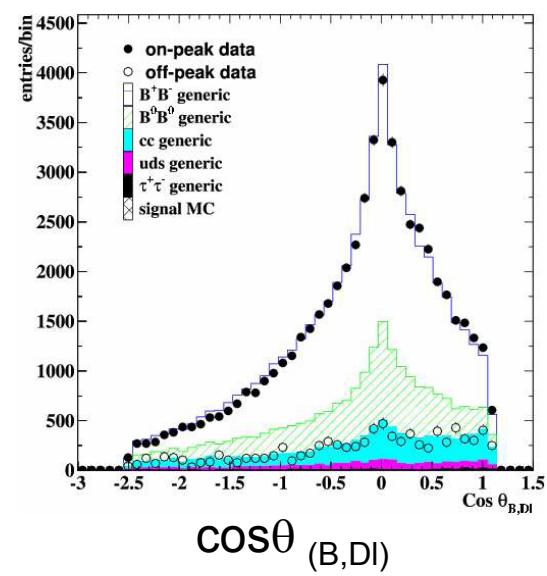


- Semileptonic Tag analysis:** The variable $\cos\theta_{(B, Dl)}$ puts a constraint on the signal candidates

$$\cos\theta_{(B, Dl)} = \frac{(2E_{beam}E_{Dl} - m_B^2 - m_{Dl}^2)}{2|\vec{p}_{Dl}| \sqrt{E_{beam}^2 - m_B^2}}$$

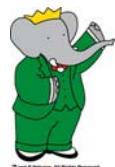
- Continuum background rejection:**

- $e^+e^- \rightarrow qq$, ($\bar{q} = u, d, s, c$) two-jet structure in CM,
- $e^+e^- \rightarrow \Upsilon(4S) \rightarrow BB$, spherically symmetric (Fox-Wolfram moments, thrust angles, sphericity)



$$B^+ \rightarrow K^+ \nu \bar{\nu}$$

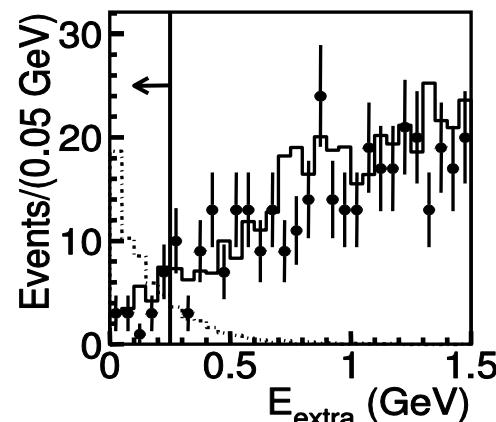
- Flavour-Changing-Neutral-Current (FCNC) process $b \rightarrow s \nu \bar{\nu}$ can occur via penguin and box diagrams with W^\pm vertices
 - No long distance contribution
 - H_{eff} gets contribution from a single Wilson coefficient C_{10}
 - Theoretically $B \rightarrow X_s \nu \bar{\nu}$ is very clean but difficult to measure, search for exclusive decay instead
 - SM: $\text{BR}(B^+ \rightarrow K^+ \nu \bar{\nu}) = (3.8^{+1.2}_{-0.6}) \times 10^{-6}$
 (G.Buchalla, G.Hiller and G.Isidori Phys. Rev D 63 014015(2001))
 Limit by CLEO: $\text{BR}(B^+ \rightarrow K^+ \nu \bar{\nu}) < 2.4 \times 10^{-4}$ (90% CL) (PRL 86, 2950 (2001))
 - Plenty of space for NP
 - Deviation from SM expectation might be a sign of a new physics
 - Two-Higgs doublet model (2HDM), light dark matter scalar particle can enhance the branching fraction by one or two orders of magnitude
 (Y.Grossman, Z.Ligeti and E.Nardi Nucl. Phys. B465 369 (1996); C.Bird et. al., PRL 93 201803 (2004))
-
- 4



$B^+ \rightarrow K^+ \nu \bar{\nu}$ (cont'd)



	Hadronic Tag
ε (%)	0.055 ± 0.005
N_{bg}	3.9 ± 1.1
N_{sig}	3

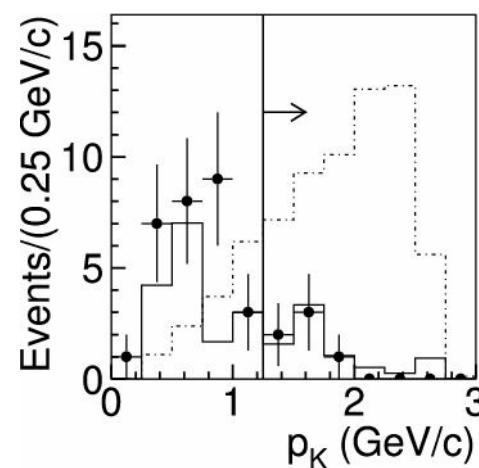


Upper limit 90% CL

82 fb^{-1} : $BR(B^+ \rightarrow K^+ \nu \bar{\nu}) < 5.2 \times 10^{-5}$ (BaBar - PRL 94, 101801(2005))

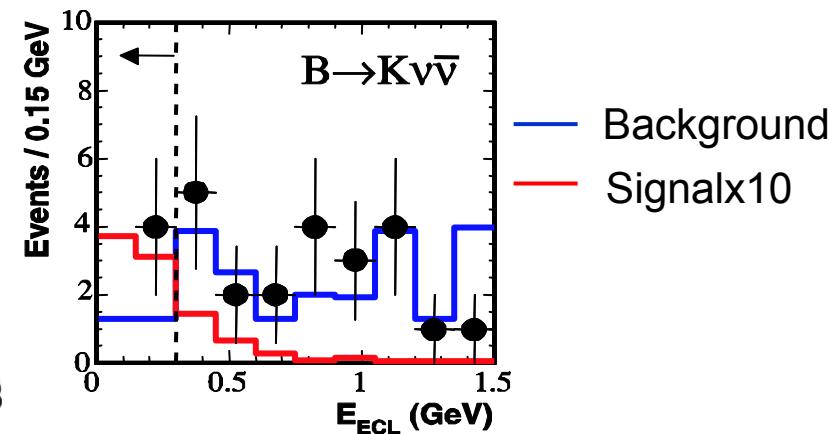
253 fb^{-1} : $BR(B^+ \rightarrow K^+ \nu \bar{\nu}) < 3.6 \times 10^{-5}$ (Belle - hep-ex/0507034)

	Semileptonic Tag
ε (%)	0.115 ± 0.009
N_{bg}	3.4 ± 1.2
N_{sig}	6



$B^+ \rightarrow D^{*(0)} X^+$
 $X = \pi, \rho, a_1$ and
 $B^+ \rightarrow D^{*(0)} D^{*+}_S$

	Hadronic Tag
N_{bg}	2.6 ± 1.6
N_{sig}	4



BaBar: Limit also set for $B^+ \rightarrow \pi^+ \nu \bar{\nu}$ by changing PID selection on the single track
 $BR(B^+ \rightarrow \pi^+ \nu \bar{\nu}) < 1.0 \times 10^{-4}$ (90% CL) (HadronicTag B only)



$B^+ \rightarrow \tau^+ \nu_\tau$

Helicity suppressed pure leptonic decay provide

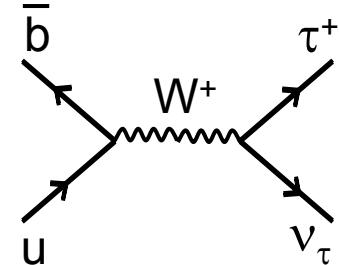
$$BR(B^+ \rightarrow \tau^+ \nu) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

(P. Harrison and H. Quinn Tech. rep. SLAC-R-504)

- Direct measurement of product of $|V_{ub}|$ and f_B
- B meson decay constant, f_B (16% LQCD, 9%, QCD sum rule)
- $BR(B^+ \rightarrow \tau^+ \nu)/\Delta m_d$ constrain on $|V_{ub}| / |V_{td}|$

- **Analysis: semileptonic tag $B^- \rightarrow D^{*0} \ell^- \nu$**
 - $D^{*0} \rightarrow D^0 \pi^0 / D^0 \gamma$; $|\cos \theta_{B,D^{*0}\ell}| < 1.1$; $p_\ell > 1$ GeV
- **Signal selection**
 - 1 or 3 track in τ decay

$$\tau^+ \rightarrow \pi^+ \nu_\tau, \pi^+ \pi^0 \nu_\tau, \pi^+ \pi^- \pi^+ \nu_\tau, \ell \nu_\ell \nu_\tau \quad (\ell = e, \mu)$$
 (81% of all τ modes)
 - Mode dependent cuts (e.g., number of tracks, PID)



$$BR(B^+ \rightarrow \tau^+ \nu) = (9.3^{+3.4}_{-2.3}) \times 10^{-5}$$

(CKMfitter 2005)

$$BR(B^+ \rightarrow \tau^+ \nu) < 4.2 \times 10^{-4} \text{ (90% CL)}$$

(BaBar, PRL 95, 041804 (2005))

Combined result from hadronic and leptonic tag using 82 fb^{-1}

Sideband region used for background subtraction:
 $350 < E_{\text{extra}} < 1000 \text{ MeV}$

$B^+ \rightarrow \tau^+ \nu_\tau$ (cont'd)

BaBar				
Channel	ε (%)	N_{bg}	N_{sig}	
$e\nu_e\nu_\tau$	$7.5 \pm 0.4 \pm 0.2$	13.4 ± 2.4	17	
$\mu\nu_\mu\nu_\tau$	$2.9 \pm 0.2 \pm 0.1$	6.2 ± 1.7	5	
$\pi^+\nu_\tau$	$8.0 \pm 0.4 \pm 0.3$	27.7 ± 5.0	26	
$\pi^+\pi^0\nu_\tau$	$2.5 \pm 0.2 \pm 0.1$	28.6 ± 4.3	31	
$\pi^+\pi^-\pi^+\nu_\tau$	$1.4 \pm 0.2 \pm 0.1$	21.6 ± 3.0	26	

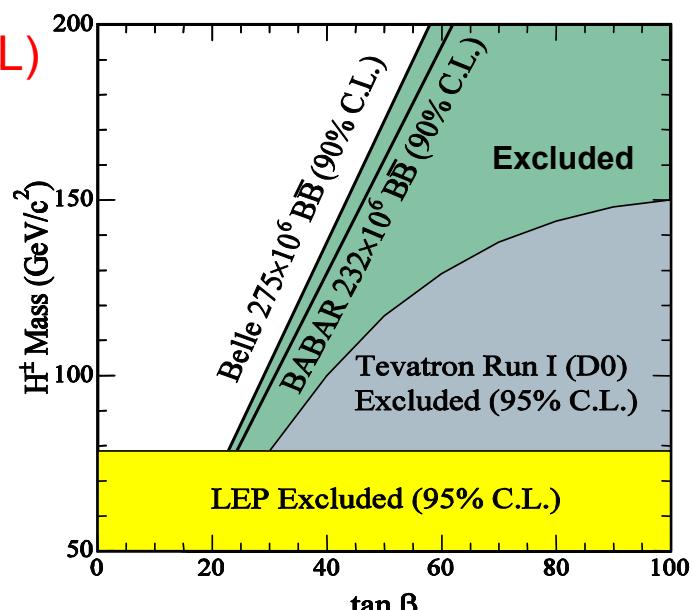
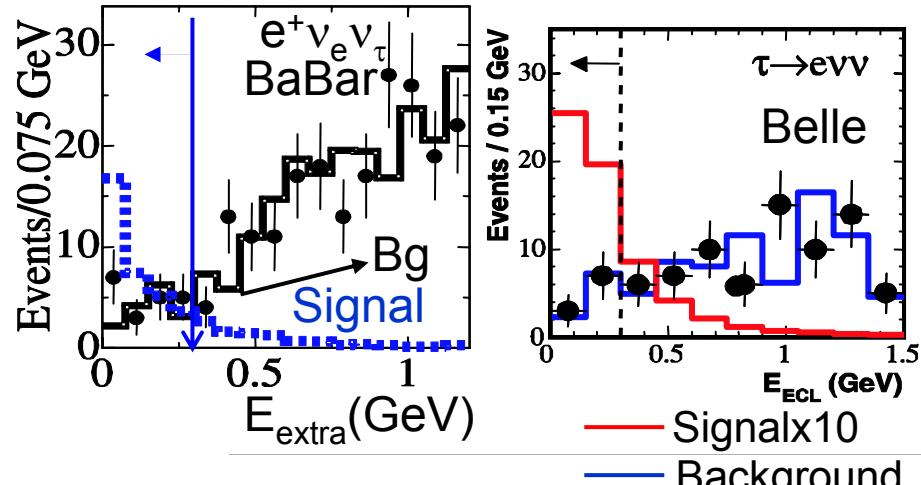
$BR(B^+ \rightarrow \tau^+ \nu) \text{ (90\% CL)}$

$< 2.6 \times 10^{-4} \text{ (210.6 fb}^{-1}, \text{ hep-ex/0507069, sub. PRL)}$

$< 1.8 \times 10^{-4} \text{ (253 fb}^{-1}, \text{ hep-ex/0507034)}$
 (Hadronic Tag B sample used also in $K\nu\nu$)

2HDM model, constrain non - SM parameters

$$BR(B^+ \rightarrow \tau^+ \nu)_{SM} \times \left(1 - \frac{\tan^2 \beta}{m_H^2} m_B^2\right)^2$$



(provided by Belle)



$B^0 \rightarrow v\bar{v}(\gamma)$

- Invisible decay helicity suppressed by $(m_\nu/m_{B^0})^2$, $\text{BR}(B^0 \rightarrow \nu\bar{\nu}) \sim 0$
 - SM prediction $\text{BR}(B^0 \rightarrow \nu\nu\gamma) \sim 10^{-9}$ (C.D. Lu and D.X. Zhang Phys. Lett. B381, 348 (1996))
 - Experimentally not observed yet
- Beyond SM: Invisible decay $\text{BR} \sim 10^{-7}\text{-}10^{-6}$ with a neutralino in final state (A.Dedes et. al., PRD 65, 015001 (2002))
- Analysis: Semileptonic Tag $B^0 \rightarrow D^{(*)-}\ell^+\nu$
 - $D^{(*)-} \rightarrow \bar{D}^0\pi^-$ and $D^- \rightarrow K^+\pi^-\pi^-$; $-2.5 < \cos\theta_{(B,D^{(*)-}\ell)} < 1.1$ (account for higher D^* mass states)
- Signal selection
 - $\nu\nu$ selection: no charged tracks; very little energy in calorimeter
 - $\nu\nu\gamma$ selection: Only one calorimeter cluster with $E_\gamma > 1.2 \text{ GeV}$ (in CM)
- Main backgrounds:
 - Charged or neutral particles which are outside the detector acceptance or unreconstructed (dominates low values of E_{extra})
 - Photons from misreconstructed π^0 (dominates $\nu\nu\gamma$ at large E_{extra})



$B^0 \rightarrow \nu\bar{\nu}(\gamma)$ (cont'd)

E_{extra} after excluding decay product of Tag B^0 and γ from $\nu\nu\gamma$ events

ML fit to the E_{extra} of signal and background distribution

a) $\nu\nu$ b) $\nu\nu\gamma$

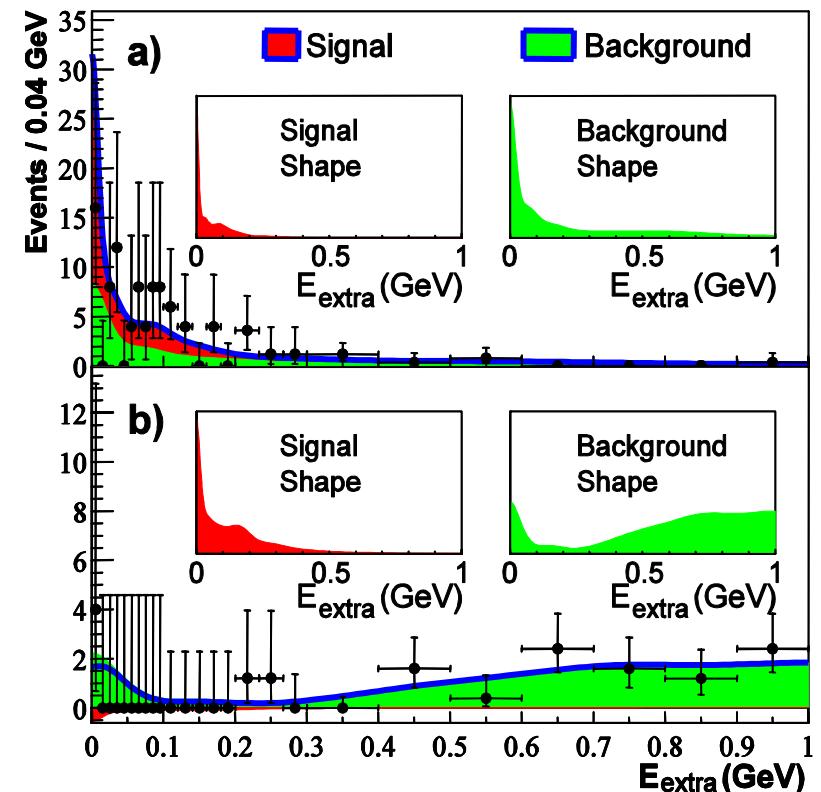
Channel	N_{sig}	N_{bg}
$\nu\nu$	17 ± 9	19^{+10}_{-8}
$\nu\nu\gamma$	$-1.1^{+2.4}_{-1.9}$	28^{+6}_{-5}

Upper limits (90% CL), 82 fb^{-1}

$$BR(B^0 \rightarrow \nu\bar{\nu}) < 22 \times 10^{-5}$$

$$BR(B^0 \rightarrow \nu\bar{\nu}\gamma) < 4.7 \times 10^{-5}$$

(PRL 93, 091802 (2004))





$B^0 \rightarrow \tau^+ \tau^-$

- Branching fraction of $B^0 \rightarrow \tau^+ \tau^-$ is less suppressed due to large τ mass

$$BR(B^0 \rightarrow \tau^+ \tau^-) = 1.2 \times 10^{-7} \times \left[\frac{f_B}{200 \text{ MeV}} \right]^2 \left[\frac{|V_{td}|}{0.007} \right]^2 \quad (\text{P. Harrison and H. Quinn Tech. rep. SLAC-R-504})$$

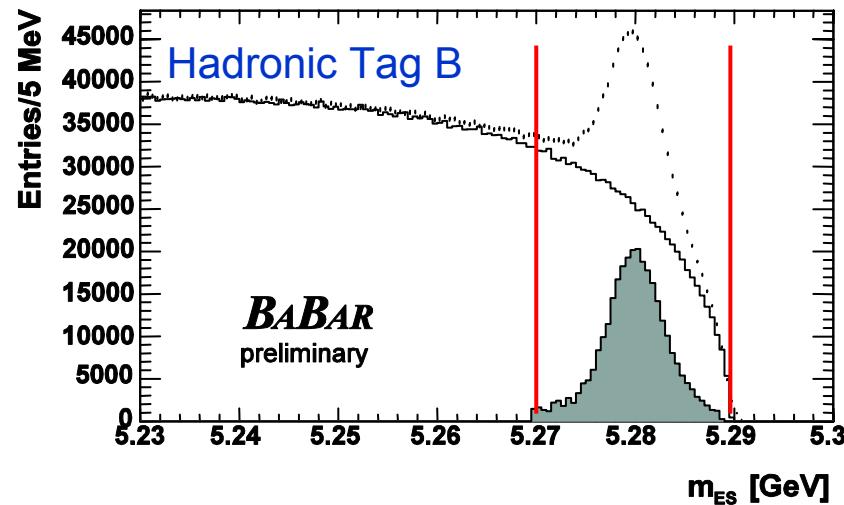
- Extension of SM: $\text{BR} \sim (\text{leptoquark coupling})^2$; 2HDM: $\text{BR} \sim (\tan\beta)^4$
- Analysis: Hadronic Tag B
 - $B^0 \rightarrow D^{(*)} X$; $D = D^+, D^0, D^{*+}$; X : up to five particles of π, π^0, K^\pm, K_s
- Signal selection:
 - Two to four neutrinos in the final state
 - $B^0 \rightarrow \tau^+ \tau^-$, where $\tau \rightarrow \nu \bar{\nu}$, $\nu \bar{\nu}$, $e \nu \bar{\nu}$, $\mu \nu \bar{\nu}$ (51% of total $\tau\tau$ decays)

- Main backgrounds :
 - not detected K_L
 - Two charged particles are outside the acceptance

Fit to m_{ES} ; $N_{\text{sig}} = 262.6 \pm 18.9$, $N_{\text{bg}} = 280.9 \pm 37.2$

Preliminary Upper limit (90% CL) 210 fb^{-1}

$$BR(B^0 \rightarrow \tau^+ \tau^-) < 2.7 \times 10^{-3}$$



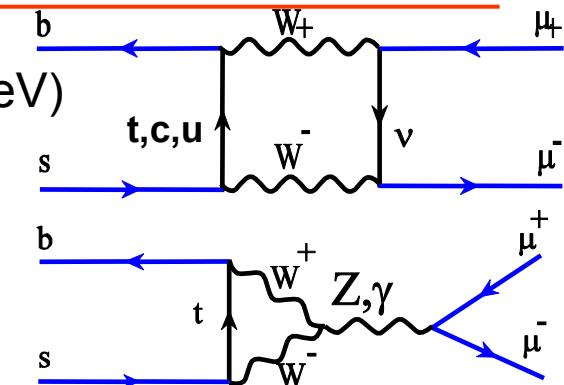


$B_s^0 \rightarrow \mu^+ \mu^- (\phi)$ from Tevatron

- B factory in pp hadron collider at Tevatron ($\sqrt{s} = 1.96$ TeV)
 $\sigma(p\bar{p} \rightarrow b\bar{b}) = 150 \text{ }\mu\text{b}$ at 2 TeV
- Expect 10^{10} $b\bar{b}$ /year, production of B_u , B_d , B_s

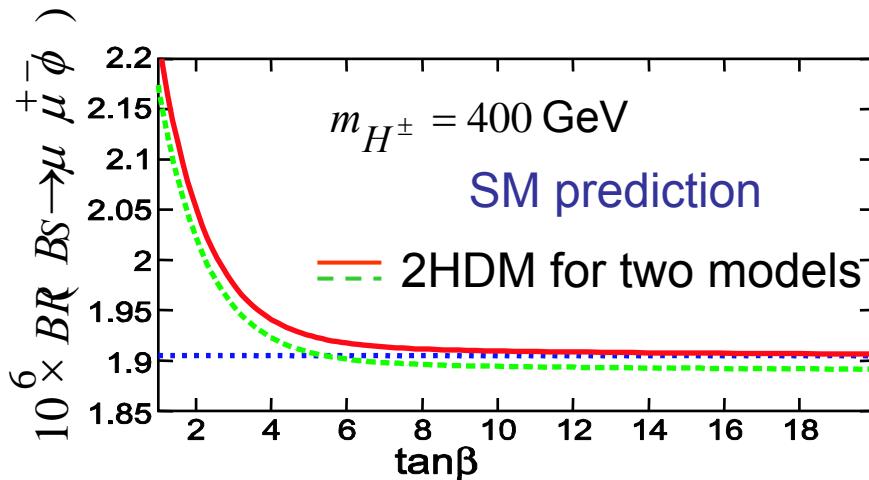
$$B_s^0 \rightarrow \mu^+ \mu^-$$

	$BR(\times 10^{-7})$	Publication
CDF	1.5	(364 pb $^{-1}$, hep-ex/0508036)
D0	4.1	(240 pb $^{-1}$, PRL 94, 071802 (2005))
SM	$(3.42 \pm 0.54) \times 10^{-9}$	(A.J.Buras, PLB 566, 115 (2003))



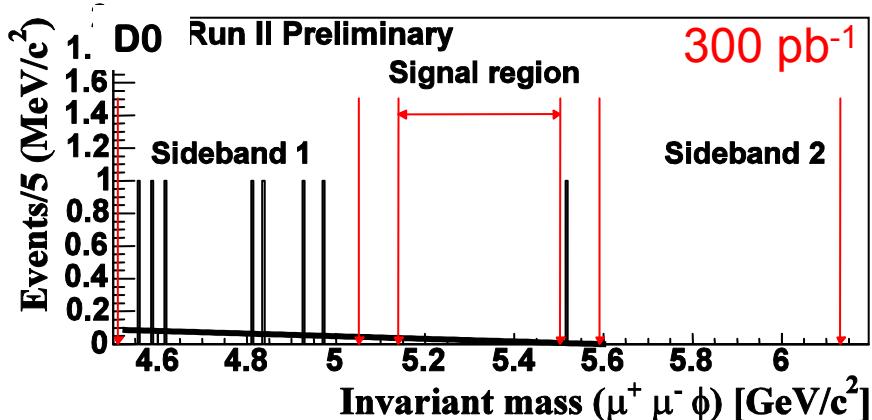
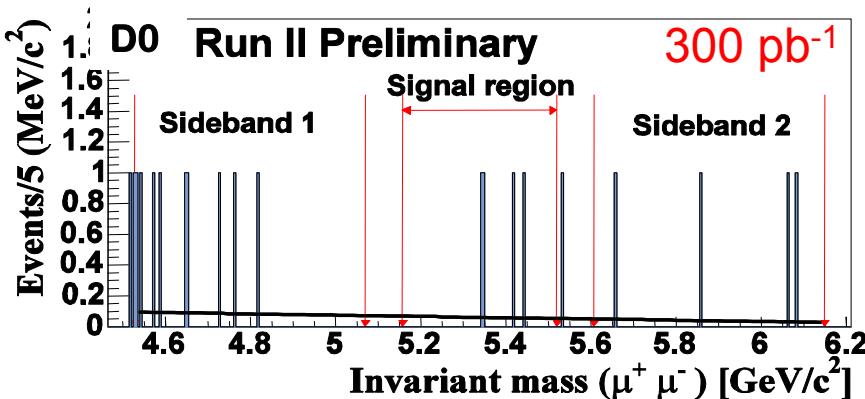
$BR(B_s^0 \rightarrow \mu^+ \mu^- \phi) = (1.6 \pm 0.48) \times 10^{-6}$
(Geng and Liu, J. Phys. G 29, 1103 (2003))

$BR(B_s^0 \rightarrow \mu^+ \mu^- \phi) < 4.7 \times 10^{-5}$ (90% C.L.)
(CDF, PRD 65 111101(2002))



- $\mu\mu$: non-SM models
 - 2HDM; MSSM: $BR \sim (\tan\beta)^4$; $(\tan\beta)^6$
 - Supergravity model: BR enhancement is correlated with sizeable positive shift in $(g-2)_\mu$
(A. Dedes, PRL 87 251804 (2001))
- $\mu\mu\phi$:
 - Increase ~15% at low $\tan\beta$
(G. Erkol, G. Turan Eur. Phys. J. C25, 575, 2002)¹¹

$B_s^0 \rightarrow \mu^+ \mu^- (\phi)$ from Tevatron (cont'd)



Expected background: 4.3 ± 1.2

Normalization channel:

$$BR(B^\pm \rightarrow J/\psi K^\pm) = (5.88 \pm 0.26) \times 10^{-5}$$

$$BR(B_s^0 \rightarrow \mu^+ \mu^-) < 3.0 \times 10^{-7} \text{ (90% C.L.)}$$

$BR(B_s \rightarrow \mu^+ \mu^-) < 1.2 \times 10^{-7}$ (90% C.L.)
Combined D0+CDF hep-ex/0508058

$B_d \rightarrow \mu^+ \mu^-$ (suppressed $\sim |V_{td}/V_{ts}|^2$)

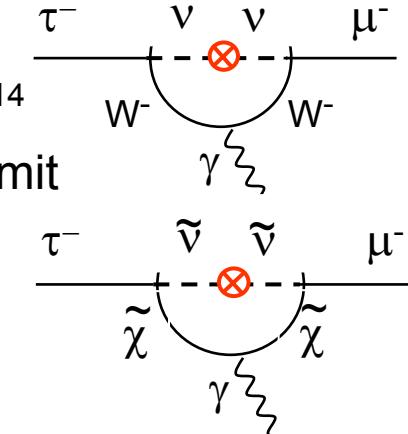
SM: $(1.00 \pm 0.14) \times 10^{-10}$

Experiment	BR(< $\times 10^{-8}$)	Publication
D0 + CDF	3.2	hep-ex/0508058
BaBar(111 fb ⁻¹)	8.3	PRL 94 221803 (2005)
Belle (78 fb ⁻¹)	16	PRD 68 111101 (2003)

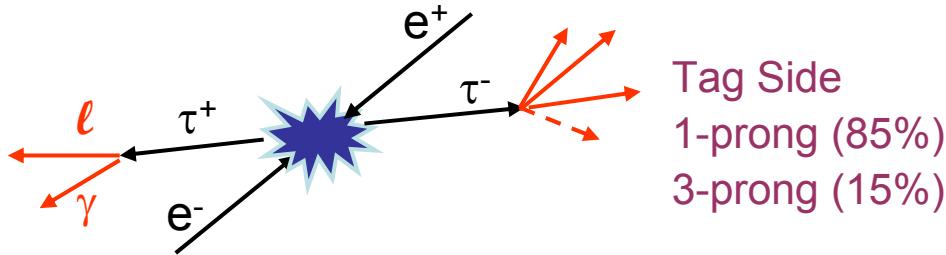
Lepton Flavour Violation in τ Decays

- Each lepton flavour is exactly conserved in Standard Model
 - SM+neutrino oscillation $\text{BR}(\tau \rightarrow \ell\gamma) \sim 10^{-40}$; $\text{BR}(\tau \rightarrow \ell\ell\ell) \sim 10^{-14}$
- MSSM, SUSY enhance the BR up to current experimental limit
 - Observation of LFV τ -decay will be clear signature of NP
- B-factory is good place to search for LFV in τ decays

$$\sigma(e^+e^- \rightarrow b\bar{b}) \sim 1 \text{ nb}, \sigma(e^+e^- \rightarrow \tau^+\tau^-) \sim 0.9 \text{ nb}$$



$\tau \rightarrow e(\mu)\gamma$ analysis strategy (BaBar)



Signal selection

Energy-constrained mass

$$m_{EC} \sim m_\tau = 1.777 \text{ MeV}/c^2$$

(Belle: $M_{inv} = l\gamma$ invariant mass)

$$\Delta E = E_{l\gamma} - \sqrt{s}/2$$

(in CM)

Main backgrounds:

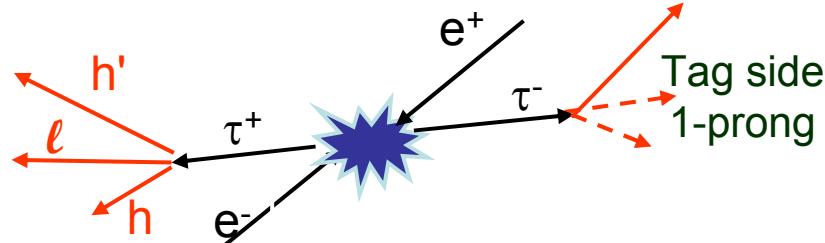
$$e^+e^- \rightarrow \ell^+\ell^- (\ell = e, \mu)$$

$$e^+e^- \rightarrow \tau^+\tau^-\gamma (\tau \rightarrow \ell\nu\nu, \gamma \text{ ISR})$$

$$\tau \rightarrow h\pi^0\nu$$

(h: hadron misidentified as muon)

$\tau \rightarrow \ell hh'$ analysis strategy ($h = \pi^\pm, K^\pm$)



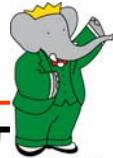
Signal selection

$$\Delta M = M_{lhh'} - M_\tau$$

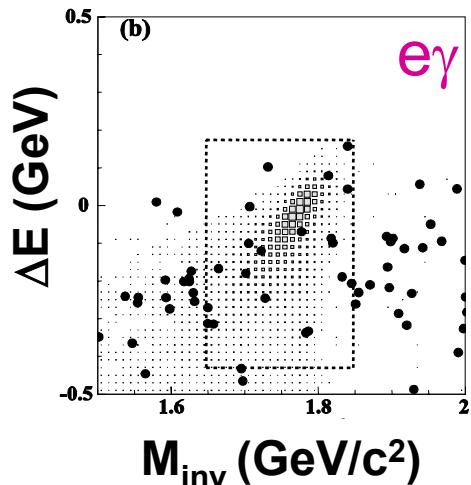
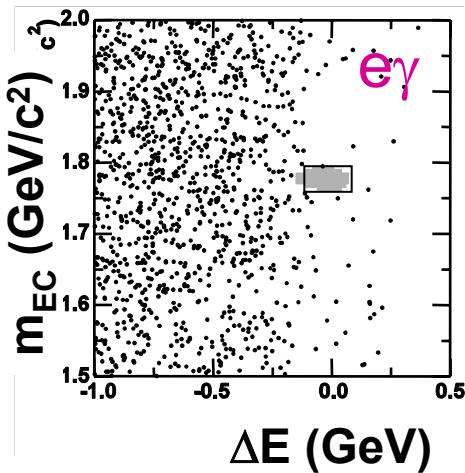
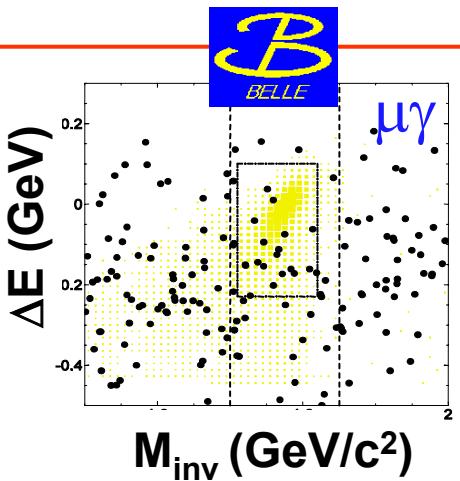
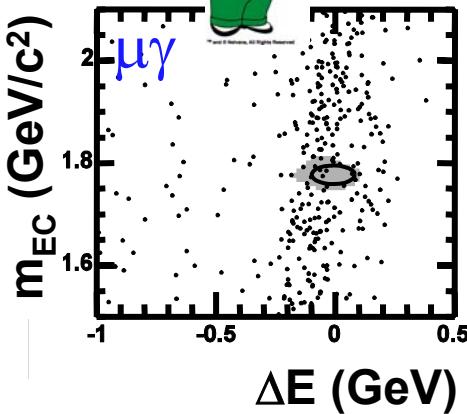
$$\Delta E = E_{lhh'}^{CM} - E_{beam}^{CM}$$

Main backgrounds:

$$\text{SM } \tau^+\tau^-, q\bar{q}$$



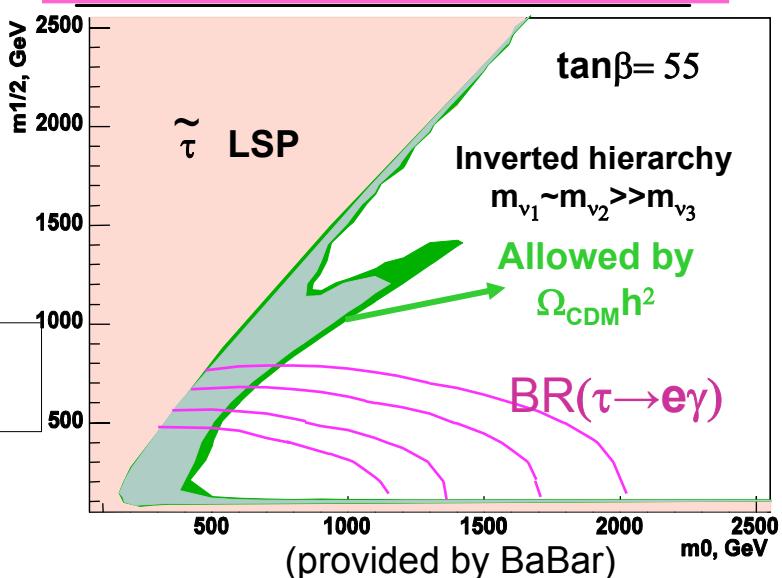
LFV - $\tau^+ \rightarrow \ell^+ \gamma$



$\mu\gamma$: PRL 92, 171802 (2004); $e\gamma$: PLB 613, 20 (2005) Belle
 $\mu\gamma$: PRL 95, 41802 (2005); $e\gamma$: hep-ex/0508012 BaBar

Exclusion plot for mSUGRA with right handed-neutrinos:
curves (from (0,0) outwards) $\text{BR}(\tau \rightarrow e\gamma) \times 10^{-7} = 1.1, 0.5, 0.2, 0.1$

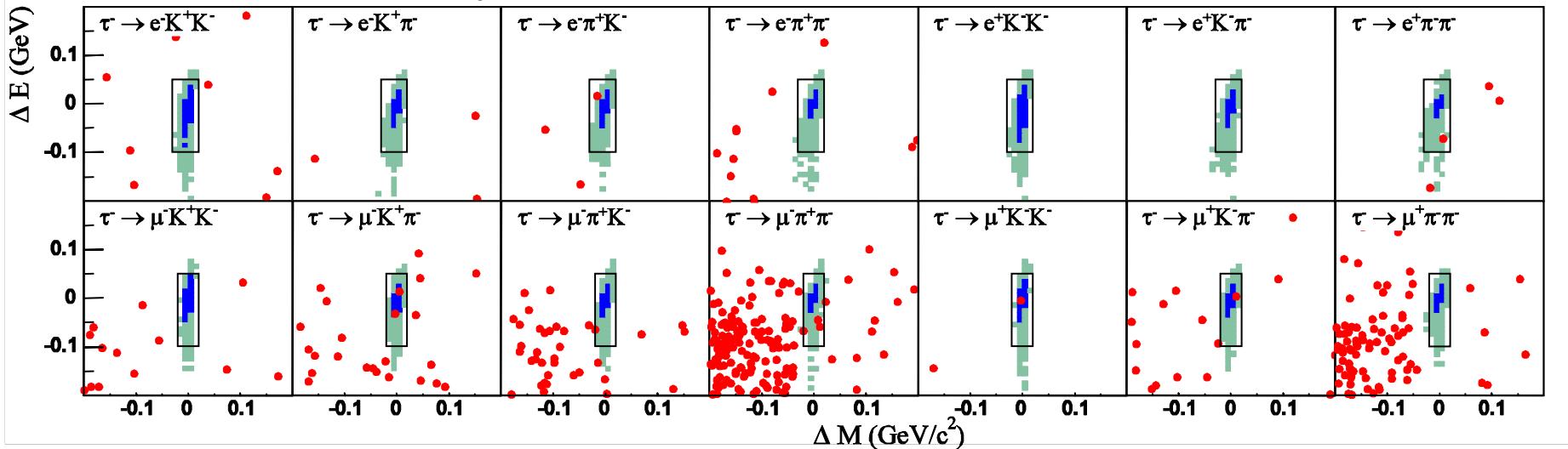
	BaBar	Belle
$L \text{ fb}^{-1} (\times 10^6 \tau\tau)$	210 (207)	86.3(78.5)
$\varepsilon (\%)$	7.4	12
N_{bg}	6.2 ± 0.5	20.2 ± 2.1
N_{sig}	4	19
$BR < (\times 10^{-7})$	0.68	3.1
$\varepsilon (\%)$	4.7	6.37
N_{bg}	1.9 ± 0.4	25.7 ± 0.3
N_{sig}	1	20
$BR < (\times 10^{-7})$	1.1	3.9



LFV - $\tau^- \rightarrow \ell^\pm h h'$

$h = \pi, K$: 14 τ -decay modes

BaBar



Number of background/channel = (0-3)

Total number of observed(expected) events = 10(11.3)

Flavour
violation

$\tau^- \rightarrow e^- K^+ K^- e^- K^+ \pi^- e^- \pi^+ K^- e^- \pi^+ \pi^- \mu^- K^+ K^- \mu^- K^+ \pi^- \mu^- \pi^+ K^- \mu^- \pi^+ \pi^-$	$BR < (\times 10^{-7})$	1.4	1.7	3.2	1.2	2.5	3.2	2.6	2.9
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$\tau^- \rightarrow e^+ K^- K^- e^+ K^- \pi^- e^+ \pi^- \pi^- \mu^+ K^- K^- \mu^+ K^- \pi^- \mu^+ \pi^- \pi^-$	$BR < (\times 10^{-7})$	1.5	1.8	2.7	4.8	2.2	0.7		Flavour + Lepton number violation
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Conclusion

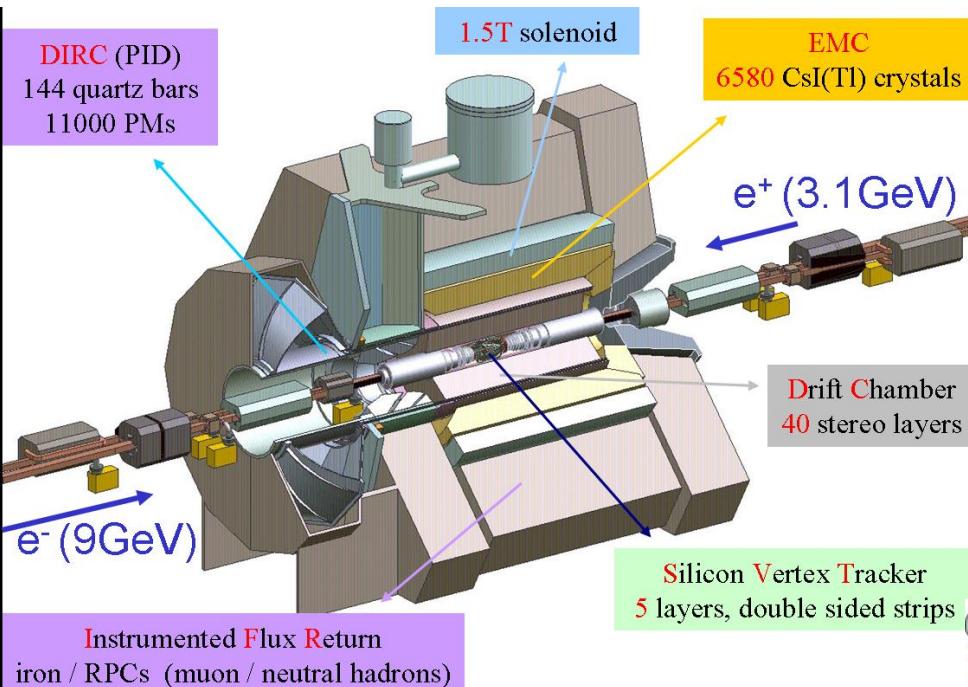
- Rare decays are important to test SM and very sensitive probe physics beyond SM
- Recent results on leptonic rare decays from BaBar, Belle and Tevatron are presented
 - No observation yet
 - f_B , CKM parameters from BR
- BaBar and Belle results on lepton-flavour violation τ decays are shown
 - Many more LFV and non-LFV channels have been looked at
 - BR of LFV decays are explained in non-SM scenarios ($\sim 10^{-7}\text{-}10^{-9}$)
 - Experimental sensitivity of 10^{-8} will be reached in a few years

BACKUP SLIDES

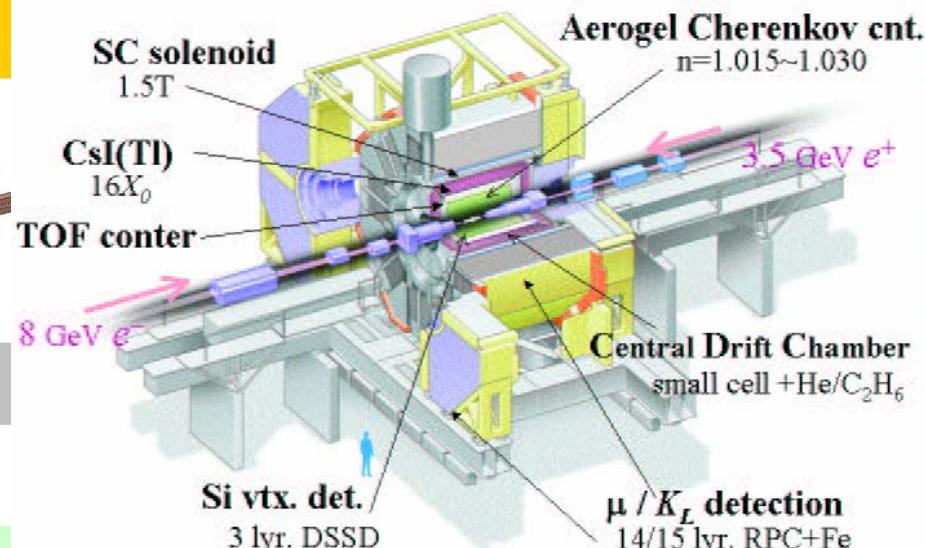
B-factories

Two asymmetric rings $\sqrt{s} = 10.58$ GeV; B mesons are produced $e^+e^- \rightarrow \gamma(4S) \rightarrow B\bar{B}$

BaBar Detector



Belle Detector



Peak Luminosity ($\times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$)	1.003
Best Day Luminosity (pb^{-1})	710
Integrated luminosity (fb^{-1})	298.96

PEPII

1.003
710
298.96

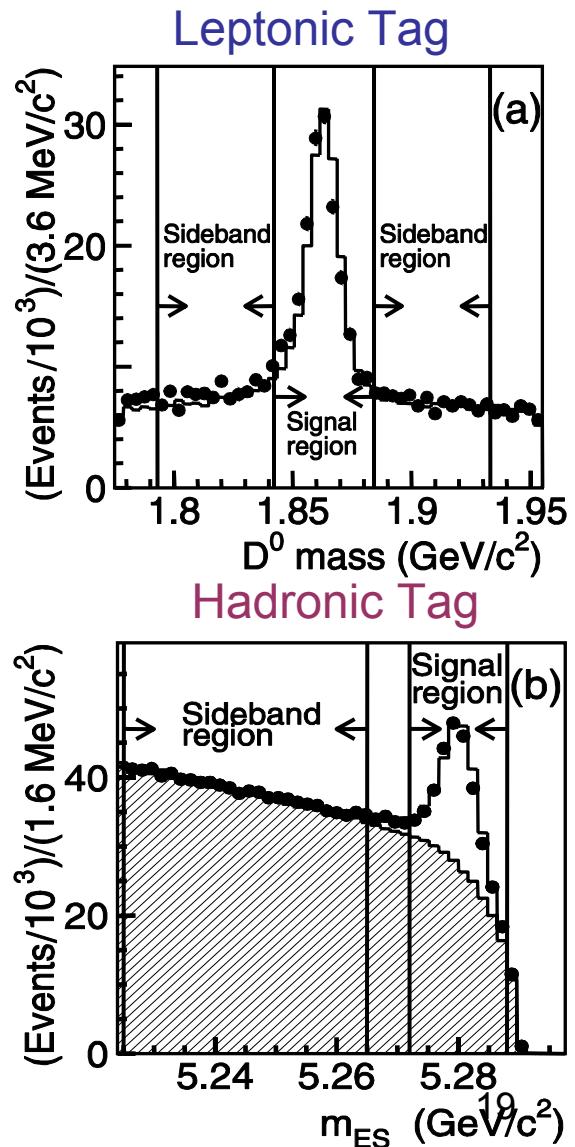
KEKB

1.581
1178
485.95 (Oct 18, 2005)



$B^+ \rightarrow K^+ \nu \bar{\nu}$ (cont'd)

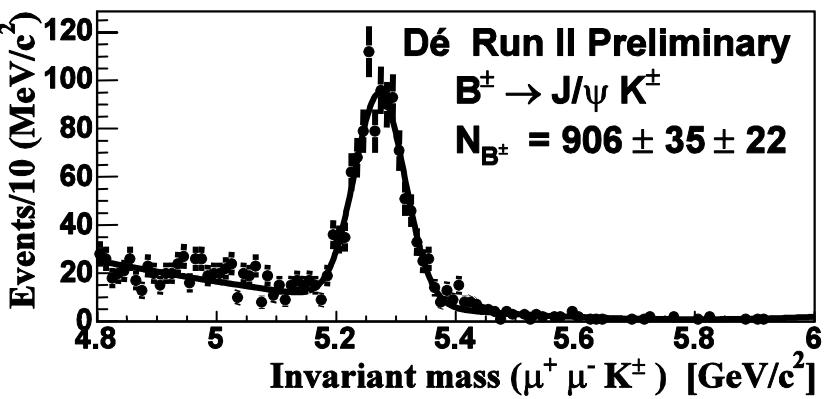
- Two analyses for $B^+ \rightarrow K^+ \nu \bar{\nu}$
 - Semileptonic $B^- \rightarrow D^0(\ell) \nu$
 $D^0 \rightarrow K^-\pi^+, K^-\pi^+\pi^-\pi^+, K^-\pi^+\pi^0$, Lepton is e or μ
 $-2.5 < \cos\theta_{B,D\ell} < 1.1$ (to account for missing particles, energy resolution)
 - Hadronic $B^- \rightarrow D^0 X$
 $D^0 \rightarrow K^-\pi^+, K^-\pi^+\pi^-\pi^+, K^-\pi^+\pi^0, K_s\pi^+\pi^-$
X is up to 5 charged tracks (π/K) and two π^0
- Signal selection
 - One single track passing Kaon PID, $p_K > 1.25$ GeV (CM)
 - $E_{\text{extra}} < 250$ MeV (very little energy in calorimeter)
- Background subtraction
 - Combinatorial bg.: D^0 mass sideband, m_{ES} sideband
 - Continuum bg.: Off-peak data
 - Peaking bg: $B^+ B^-$ events



$B_s^0 \rightarrow \mu^+ \mu^- (\phi)$ from Tevatron (cont'd)

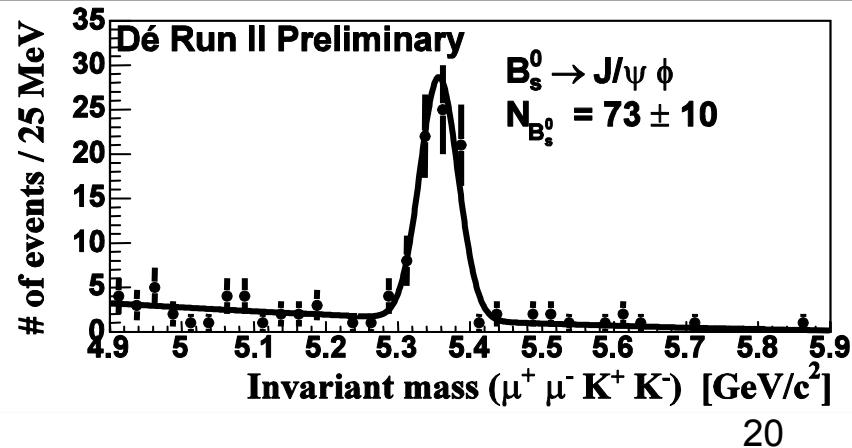
■ $\mu^+ \mu^-$ selection

- Two oppositely charged tracks
- $4.5 < m(\mu^+ \mu^-) < 7.5 \text{ GeV}/c^2$
- Each muon (p_T) _{μ} > 2.5 GeV, $|n|(\text{pseudorapidity}) < 2$
- $\min(p_T)$ of B_s candidate 5 GeV
- Decay length, $L_{xy} < 0.15 \text{ mm}$ (transverse to the beam line)
- Normalization channel $B^\pm \rightarrow J/\psi K^\pm$ $p_T(K^\pm) > 0.9 \text{ GeV}$, $\chi^2 < 20$ (vertex of J/ψ and K^\pm)



■ $\mu^+ \mu^- \phi$ selection (addition to $\mu^+ \mu^-$ selection)

- $0.5 < m(\mu^+ \mu^-) < 4.4 \text{ GeV}/c^2$ (exclude cc resonances $J/\psi \rightarrow \mu^+ \mu^-$, $\psi(2S) \rightarrow \mu^+ \mu^-$)
- ϕ : two kaon tracks with $1.008 < m_\phi < 1.032 \text{ GeV}/c^2$
- Normalization channel $B_s^0 \rightarrow J/\psi \phi$ (same cuts as above except $\mu^+ \mu^-$ pairs is within $\pm 250 \text{ MeV}/c^2$ of J/ψ mass)



(semi)Leptonic Decays

Channel	BaBar	Belle	Tevatron
$B^+ \rightarrow K^+ \nu \bar{\nu}$	5.2×10^{-5}	3.6×10^{-5}	
$B^+ \rightarrow \tau^+ \nu_\tau$	2.6×10^{-4}	1.8×10^{-4}	
$B^0 \rightarrow \nu \bar{\nu}$	22×10^{-5}	---	
$B^0 \rightarrow \nu \bar{\nu}(\gamma)$	4.7×10^{-5}	---	
$B^0 \rightarrow \tau^+ \tau^-$ (prel.)	3.2×10^{-3}	---	
$B_s^0 \rightarrow \mu^+ \mu^-$	---	---	1.2×10^{-7}
$B_d^0 \rightarrow \mu^+ \mu^-$	8.3×10^{-8}	1.6×10^{-7}	3.2×10^{-8}
$B_s^0 \rightarrow \mu^+ \mu^- \phi$	---	---	$4.7 \times 10^{-5} / 3.2 \times 10^{-6}$

τ -Decays

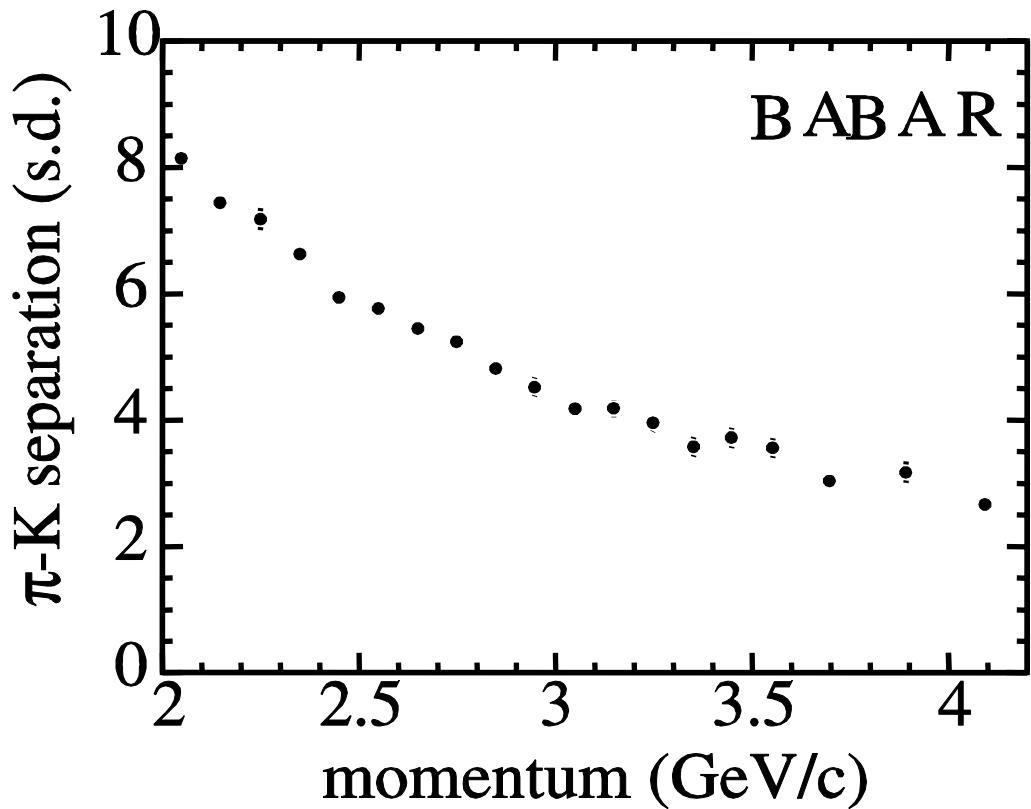
τ decay channel	BaBar	Belle
$\tau^+ \rightarrow e^+ \gamma$	1.1 (hep-ex/0508012)	3.9 (PRL 613 (2005) 22)
$\tau^+ \rightarrow \mu^+ \gamma$	0.68 (PRL 95 (2005) 041802)	3.1 (PRL 92 (2004) 171802)
$\tau^+ \rightarrow l^\mp h h'$	(7 - 48) (hep-ex/0506066, sub. PRL)	-
$\tau^+ \rightarrow l l l$	(1-3) (PRL 92 (2004) 121801)	(1.9 - 3.5) (PLB 598 (2004) 103)
$\tau^+ \rightarrow l h \ (l = e, \mu \ h = \eta, \eta', \pi^0)$	---	(1.5 - 10) (PLB 622 (2005) 218)
$\tau^+ \rightarrow \mu^+ \eta$	---	3.4 (PRL 93, (2004) 081803)
$\tau^+ \rightarrow l K \ (l = e, \mu)$	---	(5.6, 4.9) (hep-ex/050914)
$\tau^- \rightarrow (\bar{A}/A)\pi^-$	---	(0.72, 1.4) (hep-ex/0508044, subm PLB)
$\tau^+ \rightarrow l K_S^0 \ (l = e, \mu)$	---	(0.56, 0.49) (hep-ex/0509014)

BaBar

$BR(\tau^- \rightarrow 4\pi^- 3\pi^+(\pi^0)\nu_\tau) < 4.3(2.5) \times 10^{-7}$ (90% CL) (PRD 72 (2005) 012003)

$BR(\tau^- \rightarrow 3h^- 2h^+\nu_\tau) = (8.56 \pm 0.05 \pm 0.42) \times 10^{-4}$ (hep-ex/0505004) 22

K- π seperation



2.5 σ K/ π seperation up to 4 GeV